Heimbeck & Bramhall

Requirements and design of a fireproof warehouse

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REQUIREMENTS AND DESIGN OF A FIREPROOF WAREHOUSE

BY

WALTER CARL HEIMBECK

AND

RALPH ROGER BRAMHALL

THESIS

FOR THE

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

A. R. Bramhall and W. C. Heimbeck

ENTITLED "Requirements and Design of a Fireproof Warehouse"

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Architectural Engineering

James M White
Instructor in Charge

APPROVED: N. Clifford Ricker

HEAD OF DEPARTMENT OF Architecture.

Requirements and Design of a Fire-proof Warehouse.

In rural communities any building which will keep out the elements is considered suitable for warehouse purposes but in the larger cities a special type of building has recently been developed which represents as great an advance in planning and construction as can be found in any of the many other special lines of building work.

From the standpoint of the patron the requirements of the type of warehouses may be outlined as follows:-

1. Accessibility in location.
2. Modern conveniences for handling goods.
3. Low rates for storage.
4. Perfect safety for stored goods.

Considered from the standpoint of the warehouse man the above requirements are just as vital. He must also consider:-

1. Types of construction to insure the minimum insurance rates.
2. Adequate fire-protection.

Previous to the present day type of warehouse, so called mill or slow burning construction seemed to meet all the requirements of a warehouse. Now this type is fast becoming absolete, and even when protected with sprinkler systems, automatic fire alarms, etc., it falls far below the standards of storage warehouses of today.

There are only two types of construction which may be considered to fairly meet the above requirements for the standard

warehouse;- the modern fire proof building with a protected steel skeleton and brick walls: and the mill or slow burning construction, of restricted height and area, and with a complete complement of apparatus for fire protection. Unquestionably the first mentioned is the type best adapted in every way to meet the requirements and is the one chosen by the writers for their thesis design.

In this type of construction a steel skeleton supports the walls and floors, the floor system being either tile or reinforced concrete finished with a troweled cement surface; tile partitions surround various room units; and there need be no interior or exterior wood framing or finish. It also includes standard shafts with ample fire coverings for elevators, stairways and all vertical openings, and the proper safe guarding of all wall openings from exposure to fires in adjacent structures.

In considering this subject, it is the aim of the writers to give the requirements of a modern type of storage warehouse, and to design such a one, as will in every way practically conform with such requirements. At first it was deemed advisable to collect all information and data, as to requirements, from the various building ordinances of the larger cities of the United States but these were found to vary so extensively in detail and to be so nearly uniform in prime requisites that this course was abandoned.

The best alternative seemed to be to follow the Uniform Building Code recommended by the National Board of Fire Under-

writers and in so far as possible our design conforms to the requirements of this code pertaining to warehouse construction. All references here-in-after made to "standard" or "approved" forms refer to the standards adopted by the National Board of Fire Under writers.

Walls:-

For convenience in referring to the plans the warehouse will be assumed as facing North. The two exterior or enclosing walls on the North and East were considered bearing walls concerning which the Code requires:-

For warehouses the parapet wall shall not be less than twelve inches in thickness and must be carried three feet above the roof line. These walls must also be coped with stone, terra cotta or cast iron. The minimum thickness of all exterior walls carrying the loads of floors and roof must be made in accordance with the following table:-

Height	Warehouse Class - Brick Walls Min. thickness in inches.											
	Basement		Stories									
	Stone	Brick	1	2	3	4	5	6	7	8	9	10
1. Story	20	16	12									
2 Stories	20	16	12	12								
3 Stories	20	16	12	12	12							
4 Stories	24	20	16	16	16	12						
5 Stories	28	24	20	16	16	16	12					
6 Stories	32	28	24	20	20	20	16	16				
7 Stories	32	28	24	20	20	20	20	16	16			
8 Stories	36	32	24	24	24	20	20	20	16	16		
9 Stories	36	32	28	24	24	24	20	20	20	16	16	
10 Stories.	36	32	28	28	24	24	24	20	20	20	16	16

" If the clear span between bearing walls be over twenty five feet such walls shall be four inches thicker than required in the table above, for every twelve and one half feet or fraction thereof that these walls are more than twenty-five feet apart, or shall have instead of the increased thickness such piers or buttresses as may be necessary."

" The inside thickness of all walls may be built of hard burned hollow brick, properly tied and bonded by means of full header courses every sixth course into walls, and of the thickness of ordinary brick. Hollow tile or porous terra cotta, where used for furring for walls are not to be included in the thickness of the walls."

The enclosing walls on the South and West portions are of brick supported on the steel skeleton frame work. " These walls are non-bearing walls and should not be less than twelve inches for sixty feet of the uppermost height or nearest tier of supporting beams to that height. For the lower section of sixty feet or nearest tier to that height the thickness shall be increased four inches."

HEIGHT OF STRUCTURE:-

In accordance with the requirements of the building code no structure to be used above the ground floor as a warehouse, shall exceed 100 feet in height. This distance does not include cornices which do not extend more than five feet above the heighest point of the roof beams, nor the enclosure for machinery of elevators which do not exceed fifteen feet in height. Story

heights for the following given thicknesses of walls shall not exceed:--

1st. story------------------- 16 ft. in the clear.

2nd. story------------------- 14 ft. in the clear.

3rd. story------------------- 12 ft. in the clear.

4th. and Upper stories------- 11 ft. in the clear.

In buildings under one hundred feet in height, provided the height does not exceed four times the average width of the base the wind pressure may be disregarded.

FLOORS:-

Floors loads used in all computations consisted of the actual weight of walls, floors and partitions. Each floor beam was figured to support a partition over its entire length and all girders were computed for full partition loads. A live load of fifty pounds was taken as sufficient on the roof; the seventh floor, used for ordinary and light storage, was computed for 120 pounds per square foot., and the remaining floors, considered as storage for heavy materials of the warehouse type, 150 pounds per square foot was used. For fireproof warehouse construction the code requires that"the floors shall be constructed with iron or steel floor beams, spaced not more than five feet on centers, loads on same to cause no greater deflection than 1/30 of an inch per foot of span under the total load. Beams shall be tied together at intervals of not more than eight times the depth of the floor beams with suitable tie rods."

Porous terra cotta tile blocks, the shells and webs of which are not to be less than 1 1/8 inches in thickness span between the steel floor beams. "Skew backs are to be used, the shells and webs of which are required to be not less than 1 1/2 inches in thickness, with the exception of that portion which extends under the lower flanges of the beams, this to be not less than two inches of solid material not interrupted by any interior cavities or spaces." "The depth of arch shall not be less than 1 3/4 inches for each foot of span, not including any portion of the depth of tile projecting below under side of beams. The tile floor may be varied not more than six inches in the span between beams if soffits of same are horizontal."

FIREPROOFING:-

All rolled steel columns, including lugs and brackets on same which support the fireproof floors, must be entirely protected with not less than four inches of hard burned terra cotta, without any air space next to the metal. Blocks of insulating material used for column covering, are to have no vertical dimension greater than six inches when in position: shells of which shall not be less than one inch in thickness. Exterior edges of brackets and similar projecting metal may project to within 7/8 inch of the surface of the fireproofing.

Exposed sides of rolled steel girders, supporting walls and steel floor beams, shall be incased with porous terra cotta, or other fire proofing material, not less than two inches in

thickness. All columns, used to support steel girders and built in inclosure walls, shall be constructed to resist fire by having a casing of brick work not less than eight inches on outside surfaces and not less than four inches on inside surfaces. Between the inclosing brickwork and the columns, there is required a space of not less than two inches same to be filled with liquid cement grout as the courses of brick work are laid up. Girders on exterior walls require proofing of four inches thickness on the outer surfaces but the extreme edge may project to within two inches of the outside surface of the proofing.

Summary of Rooms:--

In the well appointed modern warehouse certain rooms are essential, including:-

1. Office Unit.
2. Art room.
3. Piano room
4. Warehouse man's office
5. Rug room
6. Furnace room
7. Packing room
8. Excelsior storage room
9. Storage room unit.

OFFICE UNIT:-

The placing of what we may call the office unit, requires the consideration of the following:-

1. Lighting
2. Supervision
3. Convenience

Naturally it should have an abundance of light which necessitates a location next an exterior wall. It should be placed as near the front entrance as possible in order to have a complete supervision of the entrance, elevators and stairs. To fill these requirements the writers deemed it best to place this unit in the front of the building, making the elevator lock, practically part of the office unit on the first floor. This gives the best accomodations to the patrons as they may be considered in the office as soon as entering the building. In this unit there must be provided, a private office, general office desk space, a vault, and ladies and gentlemens retiring rooms, together with, customary office equipment as regards furnishings. The vault, which in this case is used for the safe storage of silver and other household valuables, requires to be situated as near the office attendant as possible. To fill this need it should be located in the general office space. A private office is also provided, which may be only inclosed with a glass and frame partition extending possibly seven (7) feet above the floor line. There is also provided a small department between the vault and the general office space which may be devoted to a stenographer. This would serve also as an information desk, and would there-by keep one of the office force in constant attendance at the entrance to the vault.

Toilet rooms for both men and women are necessary, a small retiring room for the ladies, being placed in conjunction with their toilet. Leading directly from the office unit are doors to the Art room and to the rear of the warehouse, maintaining complete supervision of these two portions from the front of the building. The finish, ornamentation and equipment of the office should be plain and substantial to harmonize with the impression of strength, solidity and endurance which the esthetic treatment of the building must assist to convey.

ELEVATOR LOCK:-

The elevator lock, including a small passenger elevator and stairs for the use of patrons, in the opinion of the writers should have natural light. This makes it necessary to locate it on an exterior wall. The lock was placed to include the front entrance as it was deemed advisable to keep this unit as much under the direct supervision of the main office as possible. The stairs are constructed of iron and the elevator lock is enclosed with six (6) inch tile partitions, extending from floor to ceiling of each story, through the top story and six (6) feet above the roof line. The lock can only be entered through one door at each floor level. As required by the building code this door is of standard construction of a type described for the room units hung to a steel frame equipped with an automatic closing device, which closes the passage in case the temperature at any story reaches that required to melt the fussible link attachment.

The roof over the elevator lock is made of reinforced concrete, with a sky light at least three-fourths (3/4) the area of the shaft. The glass in the sky light is not to be over one-eighth (1/8) inch thick and covered above and below with a strong wire netting, standard mesh no larger than one (1) inch.
With this thickness of glass a slight amount of heat in the elevator lock would quickly break the glass and allow the smoke and flames to ascend and ventilate the elevator lock. Wire glass is not to be used in any case in the sky light of the elevator shaft, Below the machinery and sheaves at the top it is required that there be placed a grating or screen of sufficient strength to support the weight of a man, and open enough to permit flames and smoke to readily pass through to the sky light provided above.

All window openings are equipped with frames, and sash made of metal glazed with wire glass, no one pane of which is to exceed seven hundred and twenty (720) square inches in size.

ART ROOM:-

There is a display room for the protection and exhibition of art treasures and requires plenty of natural light and an abundance of clear wall space. Here pictures may be placed on exhibition by artists with the assurance of a fire proof room for the protection of their products. Only one door is provided which leads directly to the main office, making this room under the direct supervision of the office attendant at all times. It is also required that the art room be decorated and ornamented in a manner befitting the purpose of the room. Chairs and a table

may be furnished for the comfort of the patrons and a proper amount of radiation installed to comfortably heat the room when necessary.

PIANO ROOM:-

Natural light and ventilation is desired for the Piano room necessitating a location next an exterior wall. Artificial heat must be supplied to maintain a uniform temperature in it as musical instruments cannot endure great variation of temperature. For heating, a hot water installation is used, fully equipped with a standard thermostatic control, to maintain a uniform temperature of about seventy (70) degrees Fahrenheit: The customary steam equipment is dispensed with owing to the fact that steam radiation is extremely hard on musical instruments. All pianos stored in this room are carefully covered with rubber tarpaulins made to fit and cover up all parts of the piano; thus protecting them from the effects of dust or possible moisture. The stools are covered separately with a heavy paper sack and set up side down on top of the pianos.

WAREHOUSE OFFICE:-

Due to the fact that the building is long and narrow and the office is a fire-proof unit by itself in the front portion, there must be provided an office for the warehouseman giving him supervision over the unloading platform and rear entrance. Since this room must also be heated, it should be located as near

the heated portion of the building as possible and in this problem is placed beyond the Art room. Rear stairs to the basement are likewise placed in the warehouseman's office keeping the entrance to this part of the building under his supervision.

RUG ROOM:-

From the nature of the articles stored in a rug department a long narrow room is required. This is equipped with two sets of racks placed on either side of a central aisle. The racks are built up of 1 1/2" gas pipe extending from floor to ceiling, and erected so as to give an unobstructed shelf to receive the rugs. A door, located at one end of the aisle is most convenient for placing or removing the rugs from storage. The rugs are thoroughly cleaned and then rolled on a pole before being stored away on the racks. During the period of storage all rugs are taken out twice a year, inspected and cleaned to insure their being in perfect condition for storage.

RECEIVING PLATFORM:-

The receiving platform is an important item in the design. It should preferably be placed so that it may be under the supervision of the warehouseman and amply large to receive several vans at the same time. It is a good idea to place the receiving platform and van entrance within the building to protect the goods from inclement weather while being unloaded. The van roadway should be paved and about 28 to 30 inches below the receiving platform level. This brings the platform and bed

of van on the same plane and makes possible the trucking of furniture directly into the van from the warehouse or vice versa. A platform of from three to three feet six inches is om ample size since the furniture is not stored thereon but immediately taken into the loft space of the first floor. The entrance to the warehouse from the receiving platform is closed with a series of folding lift steel doors, of a standard approved type, which should extend practically across the entire rear of the building.

The freight elevators are required to be as near the receiving platform as possible, preferably in direct conjunction with it. It is a good idea to so locate the elevator as to make it accessible from the van entrance. If this is possible, unloading isoften facillitated by merely backing the van into the elevator, lifting it to the required story and unloading directly from it. Such a scheme necessitates an elevator of sufficient capacity to accomodate one of the large type of city vans, and makes it possible to handle autos and other vehicles, The freight elevator inclosure should conform to the requirements of city ordinances as to enclosing walls, sky lights, gratings, windows, and door openings described under requirements of the passenger elevator. Steel doors of the standard rolling lift type should be provided at each level.

HEATING PLANT:-

In this type of building, used entirely for the storage of household effects, it is only necessary to heat that portion

devoted to the office space, with its auxilliary rooms, and the heating apparatus will necessarily be small. The hot water system with standard thermostatic control, is used as it is preferred for heating the piano room. The space alloted to the heating plant should be ample, well lighted and ventilated, and the boiler of sufficient capacity to furnish radiation for the office, piano and art room, and warehousemans office. A small space, convenient to the boiler, should be given up to the storage of coal and must be readily accessible from the exterior to facilitate the handling of coal.

PACKING ROOM:-

This feature of a well equipped warehouse deserves careful attention as there is an ever increasing demand on the warehousemen in regards to the packing and crating of household effects for shipping and storage. Here should be placed a long work bench well lighted and preferably against the exterior wall. It should be equipped with a cross cut saw and a ripper properly connected by shafting to an electric motor. Ample space must be alloted for the packing and crating of furniture. In order to reduce the insurance rates to a minimum a separate room must be provided for the storage of excelsior and other materials used in packing. Racks for the proper storage of lumber, used in making crates, should be conveniently located in the packing room.

ROOM UNIT:-

The success of the modern furniture warehouse depends

on the success of the fireproof unit. The end to be achieved in these small units is to make a separate room which is absolutely fire proof.

The walls of the rooms are usually constructed of hollow tile blocks, a tile of four inch thickness being used in this design. Four inch hollow tile partitions of hard burned clay or porous terra cotta may be built, not exceeding in their vertical portions a measurement of twenty-four feet, and in their horizontal measurement a length not exceeding seventy-five feet, unless these partition walls are strengthened by proper cross walls or built in iron or steel frames, when the latter is imbeded in or insulated by the same material of which the partition is constructed.

Several methods of constructing the room unit may be used. One plan is to construct the floor first, putting on the cement surface and finishing it complete. Upon this the partition tile may be placed as required for the room units. The objection to such a scheme comes when it is necessary to flood any one unit. There being no method to confine the water, it will flow into other units and cause unnecessary damage. With this plan there is also some difficulty in erecting and placing the doors to the room units as required by the Fire Underwriter rules.

A second method is to construct a cement curb four to six inches in height entirely around each unit upon which the tile partitions are set. This arrangement makes a water proof pan four to six inches deep of each room and in case of fire prevents the spread of water to adjacent rooms. When a unit is flooded the

water will overflow at the door threshold into the corridor, which is in itself a pan separated from the room by the curb, and properly drained at the fourth point of each corridor.

This curb may be constructed as follows:-

A simple method is to case the curbs separately and then to set them in place as required before putting on the finished concrete floor.

Forms might also be erected and the curb cast in place, finishing the floor later to the curb.

The same effect could be obtained by first setting the partition tile in place and then forming a cove up the side of the tile to the required height and form. One decided advantage of using the curb comes when framing the doors, when it is necessary to completely frame the opening with steel sections.

The door and frame used in this construction should comply with the following requirements:-

The sills are to be of steel sections, raised not less than two inches above the floor on each side of the wall. An efficient section to be used in this detail is a channel. As shown on detail sheet No. 1 a 5"-6.5# channel was used, this being sufficient to receive the tile partitions of the corridors. For the sake of economy the doors are placed in pairs hinged to one channel, which is turned to receive the tile partition between room units. Channels were used as the head and sill of each door, the one at the head turned up to receive the tile, and the sill turned down to cover and protect the concrete curb. The head and sill channels are to be securely connected to jambs by

2"-2"-3/8" fillet angles.

The door plates are to be of 3/16" steel, thoroughly straight and single plates used where practical. Each door plate must overlap the wall frame at least one inch on all sides. To stiffen the door plates, 2"-2"-3/8" angles are to be riveted continuous around the plate with connections made at corners by fillet angles. At least two angles must be riveted across the plate to stiffen it. The ends of these may be crimped and overlap the side angles as shown on the detail sheet of the same.

The doors are to be hung to frames by at least three wrought iron hinges 2"-3/8" bar iron, bent to overlap the panel frame on the hinge side. Hinges riveted to the wall frame are required to be at least 4"-3"-3/8" and must be fastened by at least three rivets. Pins used to be 5/8" turned steel.

The rivets throughout are to be of Norway iron at least 3/8" in diameter and spaced not over six inches apart. Steel rivets should never be used.

Standard metal window frames, placed at the two ends of the corridors, afford a sufficient draft to cause a constant change of air in the storage rooms. To secure ventilation in the rooms, two ventilators, of approved design with fus§ible links, opening into the corridor are placed one at the ceiling and one at the floor line. This allows sufficient draft to ventilate the rooms, yet there is not enough draft to feed a fire, should one occur.

The Standard size of room is one which has a cubical contents of about 800 cubic feet which will provide for the

storage of the household effect from a four room flat. From this the economical sizes vary up to about 1100 cubic feet contents.

A width of five feet is allowed for all aisles used for trucking, and an unloading space should be left in front of the freight elevator door.

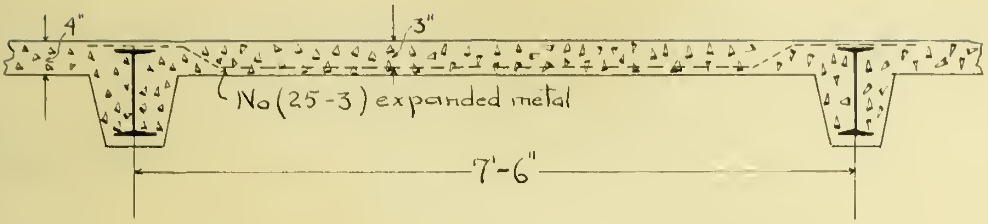
Artificial light should be supplied only in the corridors by a system of electric lighting. The wire circuit is not placed in conduits, but runs exposed on the ceiling of the corridor. Drops are taken off in front of each set of doors and are hung low enough to clear the top of the door openings. Electric light risers come up in the elevator lock in conduit and the switches for the control of each floor system are in the passenger elevator lock.

DESIGN of a FIRE-PROOF WAREHOUSE

Designed in accordance with the Building Code recommended by the "National Board of Fire Underwriters". (Third Edition 1909).

In the following concrete design, the principles and notations used in Turneaure and Maurer'text book (Principles of Reinforced Concrete Construction) will be used.

Design of Roof Slab.



$f_s = 15000 \#/\text{sq. in.}$

$f_c = 500 \#/\text{sq. in.}$

$n = 18.$

The stress-strain curve of concrete in compression may be assumed as a straight line.

Live load	$= 50.0 \#/\text{sq. ft.}$
Roofing felt	$= 5.5 \#/\text{sq. ft.}$
Slab 4"	$= 50.0 \#/\text{sq. ft.}$
Total	$= 105.5 \#/\text{sq. ft.}$

$p = 0.0065$

$R = 82.$

$$M = \frac{wl^2}{10}$$

$$= \frac{105.5 \times 7.5^2 \times 12}{10}$$

$$= 7120 \text{ in. lbs.}$$

$$d = \sqrt{\frac{M}{b \times R}}$$

$$= \sqrt{\frac{7120}{12 \times 82}}$$

$$= 2.7"$$

1.0" added for fire proofing.

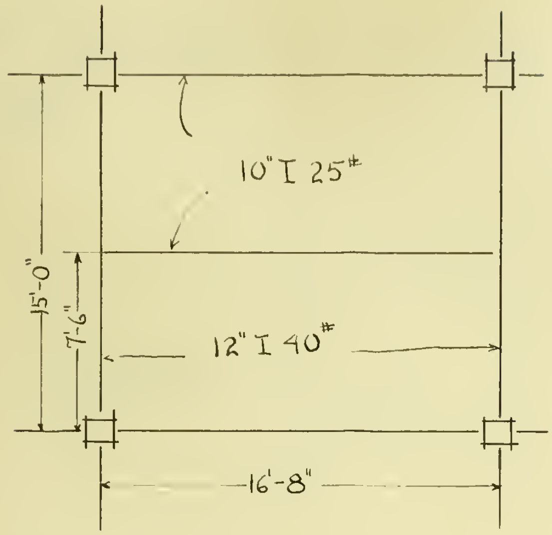
4.0" required depth of slab.

Required steel area $= 0.0065 \times 12 \times 2.7$

$= 0.21$ sq. in./ft. in width.

Use No (25-3) Northwestern Expanded Metal.

Design of Roof Beams and Girders



Design of beam.

Load/lin. ft. of beam.

Slab (105.5 x 7.5)	= 792#
Wt. of beam	= 25#
Total	= 817#

$$M = \frac{wl^2}{8}$$

$$= \frac{817 \times 16.6^2 \times 12}{8}$$

$$= 338{,}000 \text{ in. lbs.}$$

$$\frac{I}{c} = \frac{338000}{16000}$$

$$= 21.1$$

Use for roof beam 10" I 25#

Design of Girder.

Load concentrated at center of girder = 817 x 16.6

= 13550#

Assume wt. of beam as 42#/lin. ft.

$$M = \frac{13550 \times 15 \times 12}{4} + \frac{42 \times 15^2 \times 12}{8}$$

$$= 610{,}000 + 14{,}200$$

$$= 624{,}200 \text{ in. lbs}$$

$$\frac{I}{c} = \frac{624200}{16000}$$

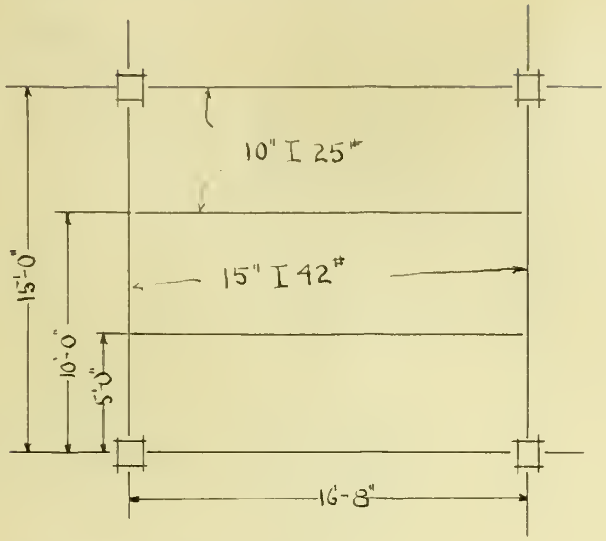
$$= 39.$$

Use for roof girder 12" I 40#

Weight of roof construction per square foot.

Live load	=	50.0
Roofing felt-4 ply	=	5.5
4" concrete slab	=	50.0
Roof beams (10" I 25#)	=	3.3
Roof girder (12" I 40#)	=	3.0
Total	=	111.8#/sq. ft.

Design of 7th floor construction



Design of floor beams.

Load/sq.ft. of floor on beams.

12" porous terra cota arch	= 36
$2\frac{1}{2}$" concrete fill	= 22
Live load	= 120
Total	= 178#/sq.ft.

Load/lin.ft. of beam.

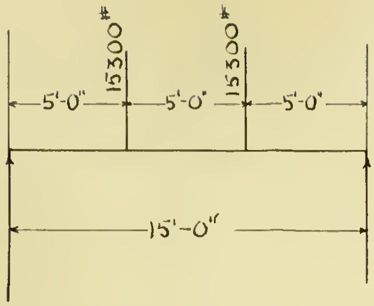
Floor (178 x 5)	= 890
Assume wt. of beam	= 30
Total	= 920#/lin.ft.

$$M = \frac{920 \times 16.6^2 \times 12}{8}$$
$$= 380{,}000 \text{ in. lbs.}$$

$$\frac{I}{c} = \frac{380000}{16{,}000}$$
$$= 23.9$$

Use for floor beam 10" I 25#

Design of girder.



Reaction of floor beam = 920 x 16.6

= 15300#

Assume wt. of girder 45#/lin ft.

$$M = 15300 \times 5 \times 12 + \frac{45 \times 15^2 \times 12}{8}$$

$$= 918000 + 15100$$

$$= 933100 \text{ in. lbs.}$$

$$\frac{I}{c} = \frac{933100}{16000}$$

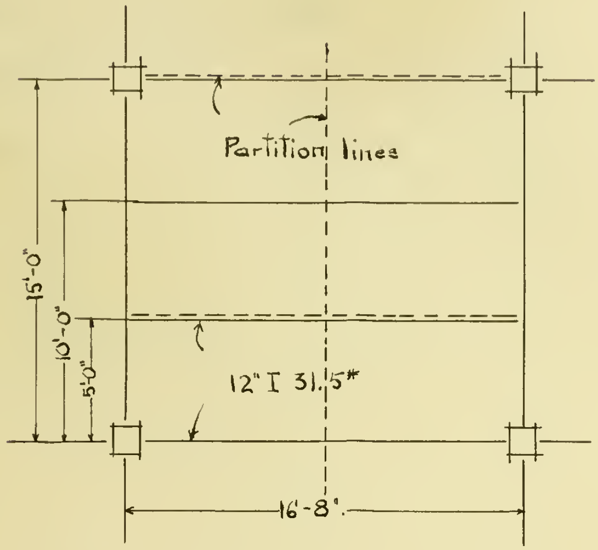
$$= 58.2$$

Use for 7th floor girder 15" I 42#

Weight/sq. ft. of 7th floor construction.

Live load	=	120.0
12" terra cota arch	=	36.0
$2\frac{1}{2}$" concrete fill	=	22.0
Floor beams (10" I 25#)	=	5.0
Girders (15" I 42#)	=	2.5
Total	=	185.5#/sq. ft.

Design of Typical Floor Construction.



Design of floor beam.

Wt./sq.ft. of floor. —

Live load	= 150
12" Terra cota arch	= 36
$4\frac{1}{2}$" concrete fill	= 40
Total	= 226#/sq.ft.

Max. load / lin.ft. of floor beam. —

Wt. of floor (226 x 5)	= 1130
Assume wt. of beam	= 35
4" tile partition (14.5 x 10)	= 145
Total	= 1310#/lin.ft

Concentrated load at center of beam due to 4" tile partition. —

(14.5 x 10 x 5) = 725#

$$M = \frac{725 \times 16.6 \times 12}{4} + \frac{1310 \times 16.6^2 \times 12}{8}$$

$$= 36100 + 542000$$

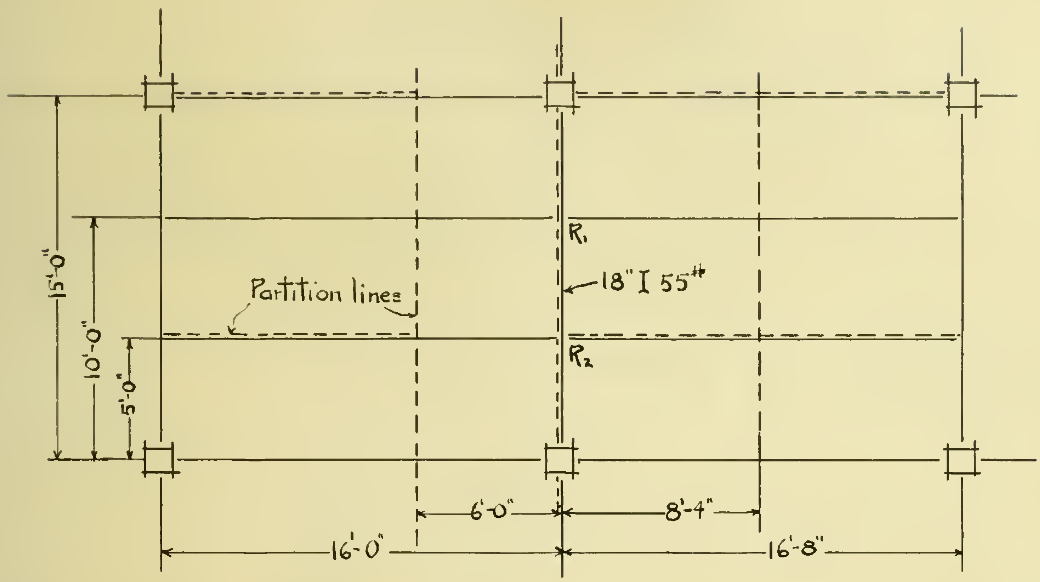
$$= 578000 \text{ in.lbs.}$$

$$\frac{I}{C} = \frac{578000}{16000}$$

$$= 36.1$$

Use for floor beam 12" I 31.5#

Design of typical floor girder.—



Determination of R_1 and R_2

Outside panel.—

$$\text{Wt. of floor} \quad \left(\frac{226 \times 83.2}{2}\right) = 9400$$

$$\text{" " cross partition} \left(\frac{14.5 \times 10 \times 5 \times 10.6}{16.6}\right) = 464$$

$$\text{" " parallel "} \left(\frac{14.5 \times 10 \times 5.3 \times 10.6}{16.6}\right) = 495$$

$$\text{" " floor beam} \left(\frac{31.5 \times 16.6}{2}\right) = \underline{262}$$

$$R_2 = 10621^{\#}$$

$$R_1 = 10126^{\#} (R_2 - \text{wt. of parallel partition})$$

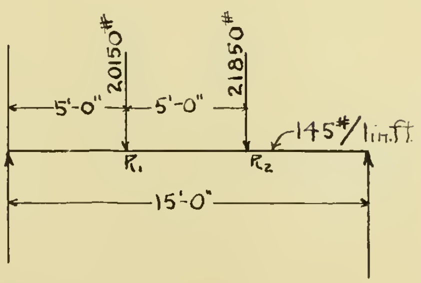
Center panel.–

Wt. of floor	$\left(\frac{226 \times 83.2}{2}\right)$	=	9400
" " cross partition	$\left(\frac{14.5 \times 10 \times 5}{2}\right)$	=	362
" " parallel "	$\left(\frac{14.5 \times 16.6 \times 10}{2}\right)$	=	1210
" " floor beam	$\left(\frac{31.5 \times 16.6}{2}\right)$	=	262
	R_2	=	11234#
	R_1	=	10024# (R_2 – parallel partition)

	R_1	R_2
Outside panel	10126	10621
Center panel	10024	11234
	20150#	21855#

Uniform load on girder.–

Tile partition (14.5 x 10) = 145#/lin.ft.



Max. moment comes at R_2.–

$$\text{Left reaction} = 145 \times 7.5 + \frac{20150 \times 10}{15} + \frac{21850 \times 5}{15}$$

$$= 21820^{\#}$$

$$M = 21820 \times 10 - \frac{145 \times 10^2}{2} - 20150 \times 5$$

$$= 109950 \text{ ft. lbs.}$$

$$\frac{I}{c} = \frac{109950 \times 12}{16000}$$
$$= 82.6$$

Use for girder 18" I 55#

Weight of typical floor construction/sq.ft.

Live load	=	150.0
12" tile arch	=	36.0
$4\frac{1}{2}$" concrete fill	=	40.0
4" tile partition	=	37.0
Floor beams (12" I 31.5#)	=	6.3
Girder (18" I 55#)	=	3.3
Total	=	272.6#/sq.ft.

Design of Framing around Freight Elevator

A —

Load/lin.ft of beam

Floor load $(226 \times 5) = 565$

Wt. of beam $= 35$

Partition $(14.5 \times 10) = 145$

Total $= 745^{\#}/\text{lin. ft.}$

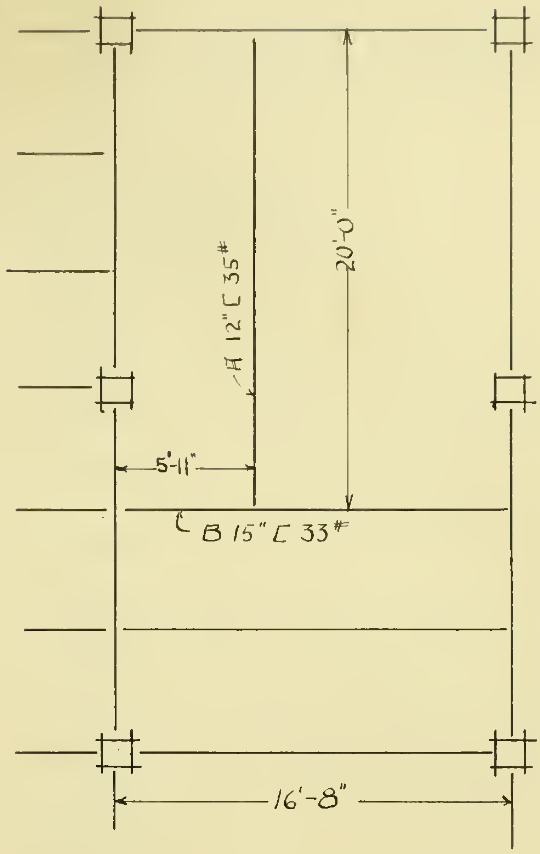
$$M = \frac{745 \times 20^2 \times 12}{8}$$

$= 446000$ in. lbs.

$$\frac{I}{c} = \frac{446000}{16000}$$

$= 27.9$

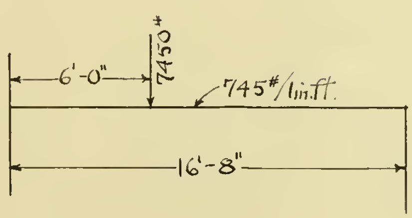
Use 12" [35#



B. —

Load/lin.ft. of beam $= 745^{\#}$

Concentrated load $(745 \times 10) = 7450^{\#}$. — 6' from support.



$$R_1 = \frac{7450 \times 10.6}{16.6} + \frac{745 \times 16.6}{2}$$

$= 10930^{\#}$

$$M = 10930 \times 6 - \frac{745 \times 6^2}{2}$$

$= 52100$ ft. lbs.

$$\frac{I}{c} = 39.1$$

Use 15" [33#

Section 137 of Building Code.

Strength of Steel Columns

In columns with flat ends, the stress/sq. in. shall not exceed that given in the following table —

When length divided by least radius of gyration equals	Working stresses/sq. in. of section
120	8240
110	8820
100	9400
90	9980
80	10560
70	11104
60	11720
50	12300
40	12880
30	13460
20	14040
10	14620

And in like proportion for intermediate ratios

Design of Interior Column.

Panel area = 16.6 x 15
= 249 sq. ft.

		Total load per story	Load at base of each 2 story section
Wt. of roof construction	= 111.8#/sq.ft.	27000#	
" " 7th floor "	= 185.5 "	46200#	73200#
" " 6th " "	= 272.6 "	67800#	
" " 5th " "	= 272.6 "	67800#	208800#
" " 4th " "	= 272.6 "	67800#	
" " 3rd " "	= 272.6 "	67800#	344400#
" " 2nd " "	= 272.6 "	67800#	
" " 1st " "	= 272.6 "	67800#	480000#

Basement and 1st story section —

Load = 480000 lbs.

Actual area = 36.76 sq. in.

Least r = 2.74

Length = 96 in.

$\frac{l}{r}$ = 35

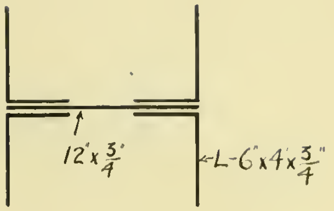
Allow. unit stress = 13170#/sq. in

Req. area = $\frac{480000}{13170}$

= 36.5 sq. in.

Eff. = $\frac{36.76}{36.5}$

= 1.01



Second and third story section —

Load = 344400 lbs.

Actual area = 29.69 sq. in.

Least r = 2.68

Length = 132 in

$\frac{l}{r}$ = 49.3

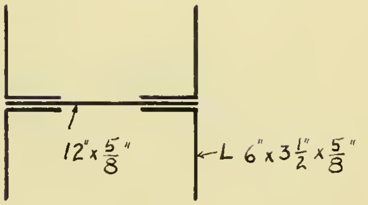
Allow. unit stress = 12360#/sq. in.

Req. area = $\frac{344400}{12360}$

= 27.9 sq. in.

Eff. = $\frac{29.69}{27.9}$

≐ 1.06



Fourth and fifth story section —

Load = 208800 lbs.

Actual area = 18.23 sq in.

Least r = 2.56

Length = 132 in.

$\frac{l}{r}$ = 51.6

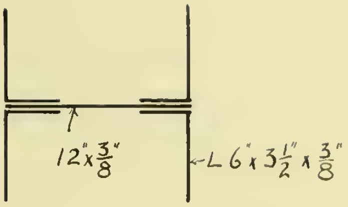
Allow. unit stress = 11370#/sq. in.

Req. area = 18.3 sq. in.

=

Eff. = $\frac{18.23}{18.3}$

= 0.997



Sixth and Seventh story section —

Load = 73200 lbs.

Actual area = 12.23 sq. in

Least r = 1.17

Length = 132 in.

$\frac{l}{r}$ = 113

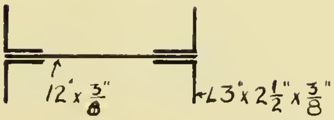
Allow. unit stress = 8650#/sq. in.

Req. area = $\frac{73200}{8650}$

= 8.46 sq. in.

Eff = $\frac{12.23}{8.46}$

= 1.45



Design of Exterior Side Wall Column.

Panel area = 16.6 x 15
= 249 sq. in.

	Floor loads lbs	Brick curtain wall lbs	Total load on each section lbs
7 and 6 story section	73200	25900	99100
5 and 4 " "	208800	63900	272700
3 and 2 " "	344400	101900	446300
1 and basement "	480000	141500	621500

Note:- designed for future extention.

Basement and first story section —

Load = 621500 lbs.

Actual area = 48.04 sq in

Least r = 3.02

Length = 96 in.

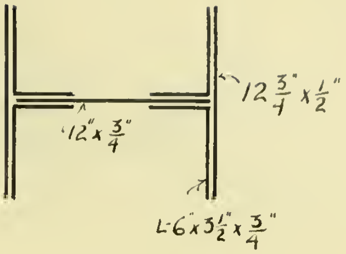
$\frac{l}{r}$ = 31.8

Allow. unit stress = 13340#/sq. in.

Req. area = $\frac{621500}{13340}$

= 46.8 sq. in.

Eff. = 1.03



Second and third story section —

Load = 446300 lbs.

Actual area = 35.29 sq. in

Least r = 2.74

Length = 132 in.

$\frac{l}{r}$ = 48.2

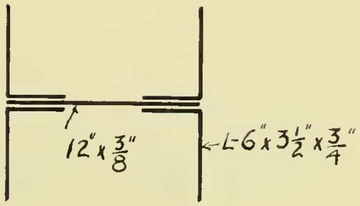
Allow. unit stress = 12420#/sq. in.

Req. area = $\frac{446300}{12420}$

= 35.9 sq. in.

Eff = $\frac{35.29}{35.9}$

= 0.985



Fourth and fifth story section.—

Load = 272700 lbs.

Actual area = 24 sq. in.

Least r = 2.62

Length = 132"

$\frac{l}{r}$ = 50.4

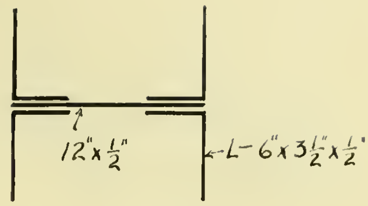
Allow. unit stress = 12300#/sq. in.

Req. area = $\frac{272700}{12300}$

= 22.2 sq. in.

Eff = $\frac{24}{22.2}$

= 1.08



Sixth and seventh story section.—

Load = 99100 lbs

Actual area = 12.23 sq. in.

Least r = 1.17

Length = 132 in.

$\frac{l}{r}$ = 113

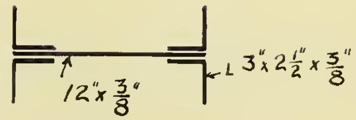
Allow. unit stress = 8650

Req. area = $\frac{99100}{8650}$

= 11.4 sq. in

Eff. = $\frac{12.23}{11.4}$

= 1.07



Design of Column No 1.

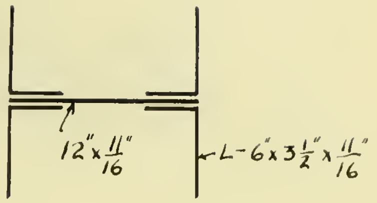
$$\text{Half panel area} = \frac{16.66 \times 15}{2}$$
$$= 124 \text{ sq. ft.}$$

	Floor loads	Brick Curtain wall	Total load on each section
7 and 6 story section	37000#	28600#	65600#
5 and 4 " "	104400#	70600#	175000#
3 and 2 " "	172200#	132600#	304800#
1 and basement	240000#	176400#	416400#

Note:— designed for future extention.

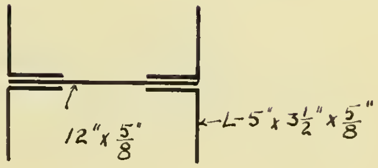
Basement and first story section.—

Load	= 416400 lbs
Actual area	= 32.48 sq. in.
Least r	= 2.71
Length	= 96 in.
$\frac{l}{r}$	= 35.4
Allow. unit stress	= 13147 #/sq. in.
Req. area	$= \frac{416400}{13147}$
	= 31.6 sq. in.
Eff.	$= \frac{32.48}{31.6}$
	= 1.03



Second and third story section.—

Load	= 304800 lbs.
Actual area	= 25.98 sq. in.
Least r	= 2.22
Length	= 132 in.
$\frac{l}{r}$	= 59.5
Allow. unit stress	= 11720 #/sq. in.
Req. area	$= \frac{304800}{11720}$
	= 26.0 sq. in.
Eff.	$= \frac{25.98}{26}$
	= 1.0



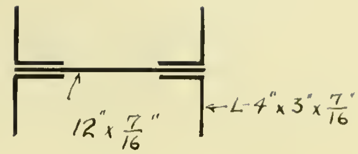
Fourth and fifth story section :—

Load = 175000 lbs

Actual area = 16.77 sq. in.

Least r = 1.64

Length = 132 in



$\frac{l}{r}$ = 80.5

Allow. unit stress = 10560

Req. area $= \frac{175000}{10560}$

= 16.6 sq. in.

Eff. $= \frac{16.77}{16.6}$

= 1.01

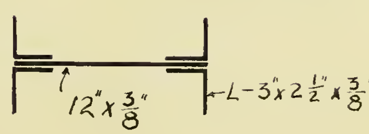
Sixth and seventh story section :—

Load = 65600

Actual area = 12.23

Least r = 1.17

Length = 132



$\frac{l}{r}$ = 113

Allow. unit stress = 8650#/sq in

Req. area $= \frac{65600}{8650}$

= 7.6 sq. in

Eff $= \frac{12.23}{7.6}$

= 1.61

Design of Column No 10.

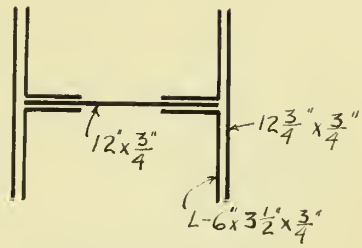
Note:- sections above (basement and first story) are similar to col. No. 1

Basement and first story section.—

Direct load $= 397000$

Load from plate girder $= \underline{170700}$

Total $= 567700$ lbs



Actual area $= 54.41$ sq. in.

$r_{2-2} = 5.4$

$l = 132$ in.

$\frac{l}{r} = 24.4$

Allow. unit stress $= 13790\#/\text{sq. in}$

Actual fibre stress $= \frac{P}{a} + \frac{My}{I - \frac{Pl^2}{24 \times E}}$

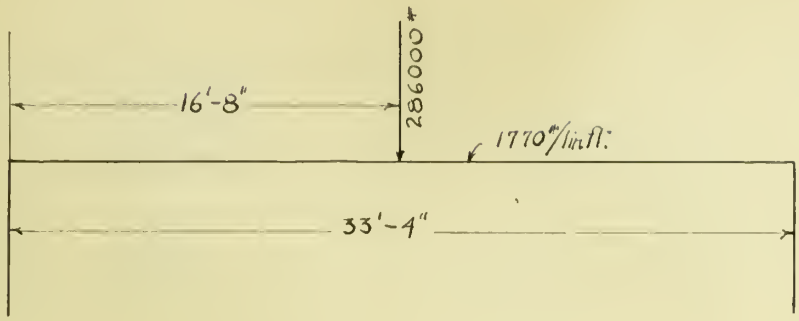
$$= \frac{567700}{54.41} + \frac{(170700 \times 6.75 - 26500 \times 6.75) \times 6.75}{1588 - \frac{567700 \times 132^2}{24 \times 29000000}}$$

$= 10400 + 4160$

$= 14560\#/\text{sq. in.}$

Allow. fibre stress $= 13790\#/\text{sq. in.}$

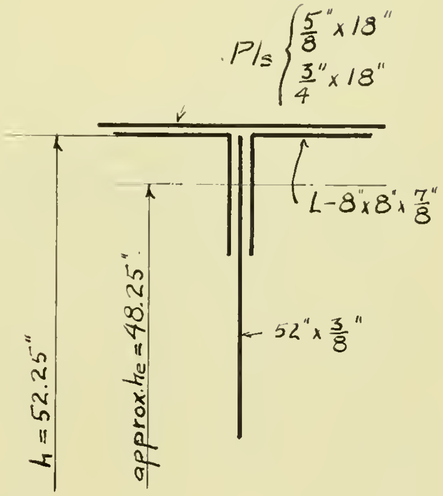
Design of Plate Girder.



Approximate design:—

Allow. fibre stress = 14000#/sq. in.

" shearing " = 9000#/sq. in.



Wt./lin ft of girder:—

$w = 124 + 12\, l$

$= 124 + 12 \times 33.2$

$= 524$#/lin. ft.

Total load/lin. ft. $= 1270 + 500$

$= 1770$#

Max. shear $= \dfrac{286000}{2} + 1770 \times 16.6$

$= 172400$ lbs.

Req. web area $= \dfrac{172400}{9000}$

$= 19.15$ sq. in.

Req. thickness of web $= \dfrac{19.15}{52}$

$= 0.368$ in.

Use for web-pl. 52" x $\frac{3}{8}$"

Max. moment $= 143000 \times 16.6 \times 12 + \dfrac{1770 \times 33.2^2 \times 12}{8}$

$= 31{,}430{,}000$ in. lbs.

Flange stress $= \dfrac{31,430,000}{48.25}$

$= 653,000$ lbs.

Flange area $= \dfrac{653000}{14000}$

$= 46.6$ sq in

1L – $8'' \times 8'' \times \frac{7}{8}''$

gross area $= 13.24$

2 rivet holes $(2 \times 0.88) = 1.76$

net area $= 11.48$ sq in.

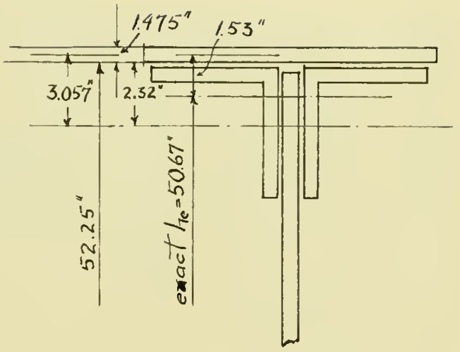
Net area of 2 Ls $= 22.96$ sq. in.

Area of flange pl. $= 46.6 - 22.96$

$= 23.64$ sq. in.

Thickness of flange pl. $= \dfrac{23.64}{18-2}$

$= 1.475$ in.



Exact design:—

Location of center of gravity of flange—

Moments about center of flange pl.

$$g = \frac{13.24 \times 2 \times 3.057}{13.24 \times 2 + 18 \times 1475}$$

$= 1.53$ in

Flange stress $= \dfrac{31430000}{50.67}$

$= 622,000$

Flange area $= \dfrac{622000}{14000}$

$= 44.4$ sq. in.

Area of flange pl. $= 44.4 - 22.96$

$= 21.44$ sq. in.

Thickness of flange pl. $= \dfrac{21.44}{18-2}$

$= 1.34$ in

Use for flange pls $\begin{cases} \frac{3}{4}'' \times 18'' \\ \frac{5}{8}'' \times 18'' \end{cases}$

Req length of flange pls.—

Length of Top pl. $\left(\frac{5}{8}''\right) = 33.2\sqrt{\dfrac{10}{44.96}}$

$= 15.6$ ft.

Length of 2nd pl $\left(\frac{3}{4}''\right) = 33.2\sqrt{\dfrac{22}{44.96}}$

$= 23.2$ ft.

Design of Footing for Outside Bearing Wall.

Wt. of wall/lin. ft.

Parapet	$3 \times 1.08 \times 115$	$= 373$
7 and 6 stories	$22 \times 1.33 \times 115$	$= 3370$
5-4-3 "	$33 \times 1.67 \times 115$	$= 6340$
2 and 1 "	$23 \times 2.0 \times 115$	$= 5300$
Basement	$8 \times 2.33 \times 115$	$= 2150$

Floorload/lin ft.

Roof	8.3×1118	$= 928$
7th floor	8.3×185	$= 1540$
6-5-4-3-2-1.	$8.3 \times 272 \times 6$	$= 13600$
Total		$= 33601$ #/lin.ft.

Assumed allow. bearing value of soil = 3 tons/sq. ft.
= 6000#/sq. ft.

$$\text{Width of footing} = \frac{33601}{6000} = 5.6 \text{ ft} = 66.2 \text{ in.}$$

Allow. vertical shearing stress = 100#/sq. in.

$$\text{Req. depth} = \frac{33601}{12 \times 2 \times 100} = 14 \text{ in.}$$

$$\text{Max. moment} = \frac{6000 \times 2.8^2 \times 12}{2} = 282000 \text{ in. lbs.}$$

$f_c = 500$#/sq. in

$f_s = 15000$#/sq. in.

$n = 18$

$p = 0.0064$

$R = 83$

$d = \sqrt{\frac{282000}{12 \times 83}}$

$= 17.1$ in

1.5 in. below rods

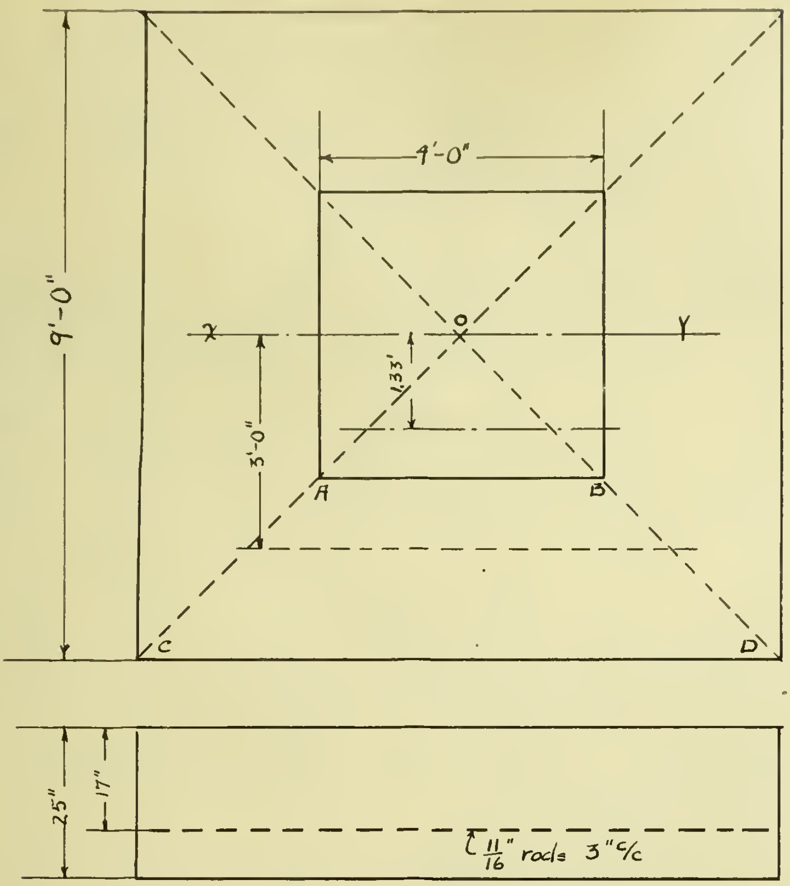
18.6 in req. depth of footing

Area of steel/ft. $= 17.1 \times 12 \times 0.0064$

$= 1.31$ sq. in.

Use $\frac{3}{4}$" ϕ rods with 4" spacing.

Design of Interior Column Footing



Floor loads at base of column = 480000

Wt. of column = 7000

Total load on base = 487,000 lbs

Allow. bearing value of soil = 6000#/sq ft.

Req. footing area $= \frac{487000}{6000}$

= 81 sq.ft.

Dimensions of footing = 9'-0" x 9'-0"

Allow. bearing value for concrete = 30000#/sq.ft.

Req. area of cast-iron base pl. $= \frac{487000}{30000}$

= 16.2 sq. ft.

Dimensions of base plate = 4' 0" x 4'-0"

Req. depth of footing for shear = $\frac{487000}{4 \times 4 \times 12 \times 100}$
= 25 in.

Upward pressure on the Δ C-O-D and the downward pressure on the Δ A-O-B are each equal to $\frac{1}{4}$ of the column load.

The max. moment is in the plane x-y.

$$M_{x-y} = \frac{505200}{4}(3 - 1.33) \times 12$$
$$= 2{,}520{,}000 \text{ in.lbs.}$$

This moment is resisted by a section, in the plane x-y, the width considered available, may be taken equal to the side of the base plate plus $1\frac{1}{2}$ x the depth of the footing = $48 + (1\frac{1}{2} \times 24)$
= 7'-0"

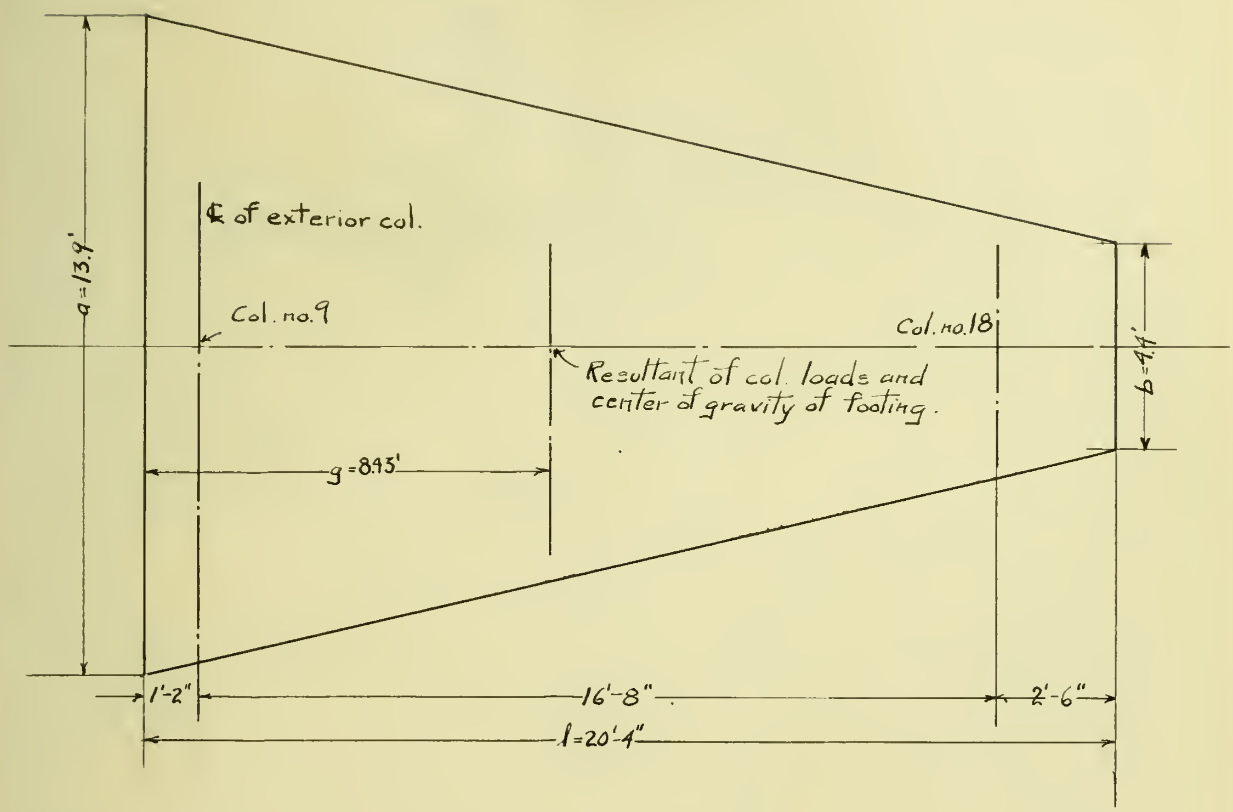
Moment/ft width of section = $\frac{2{,}520{,}000}{7}$
= 360000 in. lbs

$$d = \sqrt{\frac{360000}{83 \times 12}}$$
= 19 in.

Req. steel area = $19 \times 12 \times 0.0065$
= 1.48 sq. in.

Use $\frac{11}{16}$" ϕ rods at 3" spacing.

Design of Combined Footing
Columns No. 9 and 18.



Loads at base —

Col. No. 9.

Floor loads	=	621500#
Wt. of col.	=	8600#
Total	=	630100#

Col. No. 18.

Floor loads	=	480000#
Wt. of col.	=	7000#
Total	=	487000#

Grand total = 1,117,000#

Allow. bearing value of soil $= 6000^{\#}/\text{sq.ft.}$

Req. footing area $= \dfrac{1{,}117{,}000}{6000}$

$= 186 \text{ sq. ft.}$

Location of center of gravity of footing area.—

$$g = \frac{630000 \times 1.16 + 487000 \times 17.8}{1\,117\,000}$$

$= 8.43 \text{ ft.}$

$$b = \frac{2A}{l}\left(\frac{3g}{l} - 1\right)$$

$$= \frac{2 \times 186}{20.33}\left(\frac{3 \times 8.43}{20.33} - 1\right)$$

$= 4.39 \text{ ft.}$

$$a = \frac{2A}{l} - b$$

$$= \frac{2 \times 186}{20.33} - 4.39$$

$= 13.9 \text{ ft.}$

Design of I beam base for Col. No. 9.—

Load/ft of pl. $= \dfrac{630100}{12}$

$= 52500^{\#}/\text{lin. ft.}$

$$M = \frac{52500 \times 6^2 \times 12}{2}$$

$= 11{,}300{,}000$ in lbs

$$\frac{I}{c} = \frac{11\,300\,000}{16000}$$

$= 706.$

Use 4 — 24" Is $85^{\#}$.

Design of concrete base:-

Moment on a strip 12" wide $= \dfrac{6000 \times 16.6^2 \times 12}{8}$

$= 2{,}480{,}000$ in lbs

$d = \sqrt{\dfrac{2480000}{12 \times 83}}$

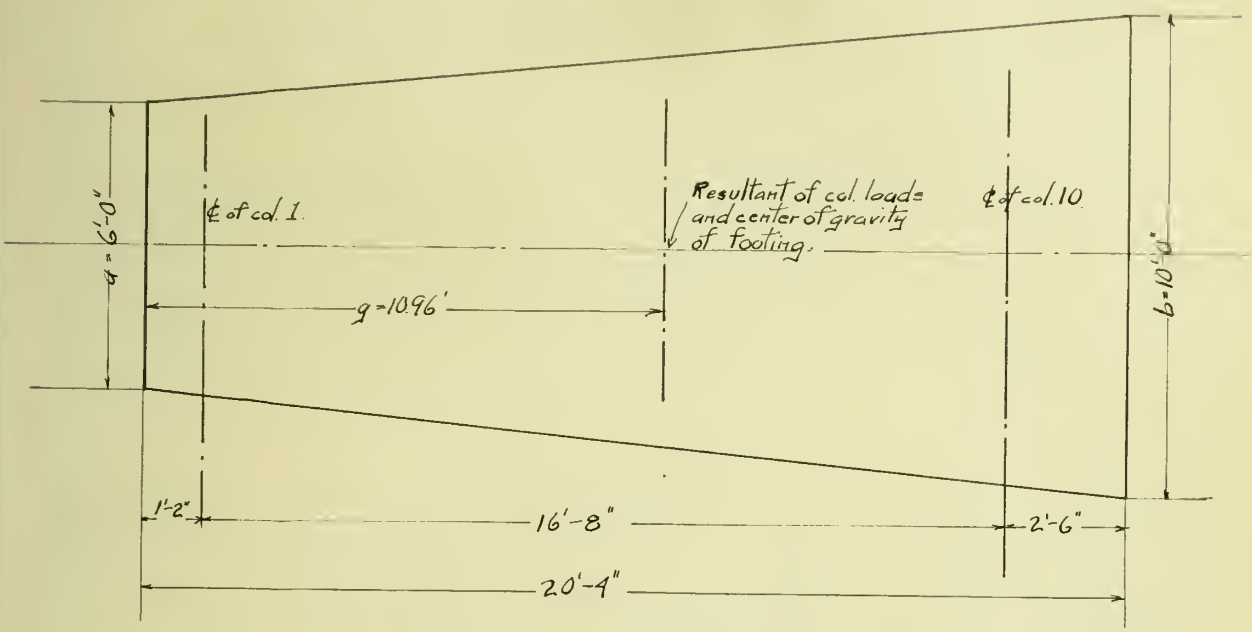
$= 50$ in.

Area of steel req. $= 50 \times 12 \times 0.0065$

$= 3.9$ sq. in.

Use $1\frac{3}{8}$" ϕ rods at $4\frac{1}{2}$" c/c

Design of Combined Footing for Column Nos. 1 and 10.



Loads at base. —

Col. No. 1. —

Floor loads	=	397400
Wt. of col.	=	6400
Total	=	403800#

Col. No. 10. —

Floor loads	=	568100
Wt. of col	=	7900
Total	=	576000#

Grand total = 979800#

Req. footing area $= \frac{979800}{6000}$

= 163 sq. ft.

Location of center of gravity of footing area –

$$g = \frac{403800 \times 11.6 + 576000 \times 17.8}{979800}$$
$$= 10.96 \text{ ft.}$$

$$b = \frac{2 \times 16.3}{20.33}\left(\frac{3 \times 10.96}{20.33} - 1\right)$$
$$= 9.95 \text{ ft}$$

$$a = \frac{2 \times 16.3}{20.33} - 9.95$$
$$= 6 \text{ ft.}$$

Design of I beam base for Col. No. 1 –

Load/lin.ft of pl. $= \dfrac{403800}{6}$

$= 67300^{\#}/\text{lin.ft.}$

$$M = \frac{67300 \times 3^2 \times 12}{2}$$
$$= 3640\,000 \text{ in.lbs.}$$

$$\frac{I}{c} = \frac{3640000}{16000}$$
$$= 228$$

Use 3 – 18" Is 55#.

Design of I beam base pl. for Col. No. 10. –

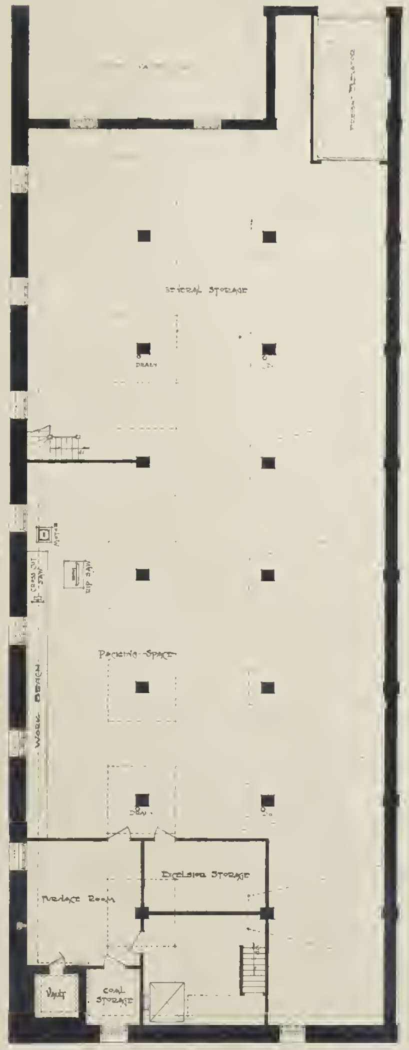
Load/lin.ft. of pl. $= \dfrac{576000}{9}$

$= 64\,000$

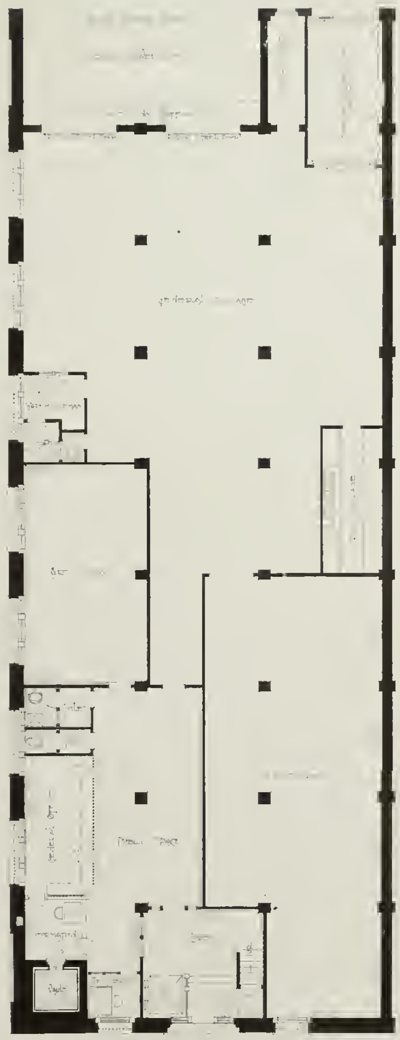
$$M = \frac{64000 \times 4.5^2 \times 12}{2}$$
$$= 7{,}760{,}000$$

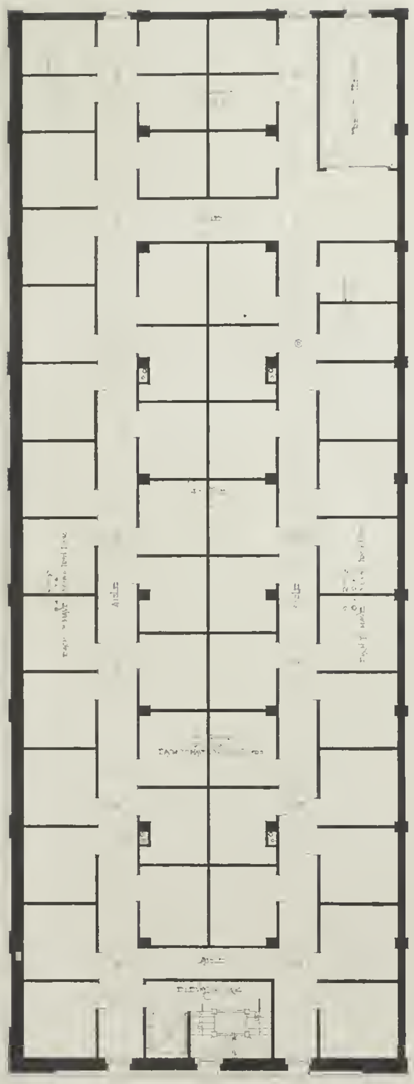
$$\frac{I}{c} = \frac{7760\,000}{16\,000}$$
$$= 486.$$

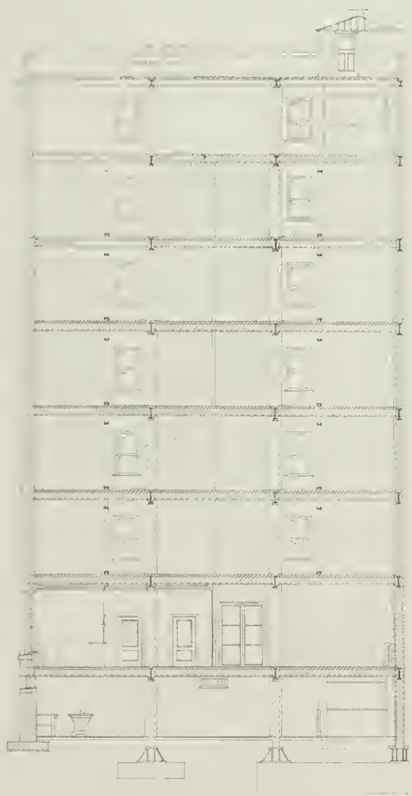
Use 4 – 20" Is 70#



THESIS
FIREPROOF WAREHOUSE
BASEMENT & FOUNDATION PLAN







THESIS
FIREPROOF WAREHOUSE
SECTION


STEEL LAYOUT